**Speed** is a precise measurement of how fast you are going. To measure speed, you need to know two things.

1) Distance  
2) Time

**Velocity** is speed with a specific direction → it is a *vector* To measure velocity you need to know three things

1) Distance  
2) Time  
3) Direction
The skier has traveled 400 meters in 6 seconds. What is his speed?

Distance traveled is ________________
The time it took was 6 seconds.
The speed is the distance traveled divided by the time taken.

\[
\text{speed} = \frac{400 \text{ meters}}{6 \text{ seconds}}
\]

\[
\text{speed} = 66.67 \text{ m/s}
\]
In this formula;

- **D** is the symbol for distance
  - Usually measured in **meters**
- **t** is the symbol for time
  - Usually measured in **seconds**
- **v** is the symbol for speed
  - Usually measured in **m/s**.

- It must agree with whatever the distance and time is measured in!

- The “v” is actually the symbol for velocity.

- Velocity is actually speed with a direction (known as a **VECTOR** quantity).

- EX: 60 mph on I-80 going east.
There are a variety of different units that we use to measure speed, because there is a variety of different units that we use to measure distance and time.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Time</th>
<th>Speed</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>meters</td>
<td>seconds</td>
<td>meters per second</td>
<td>m/sec</td>
</tr>
<tr>
<td>kilometers</td>
<td>hours</td>
<td>Kilometers per hour</td>
<td>km/h</td>
</tr>
<tr>
<td>centimeters</td>
<td>seconds</td>
<td>Centimeters per second</td>
<td>cm/sec</td>
</tr>
<tr>
<td>miles</td>
<td>hours</td>
<td>Miles per hour</td>
<td>mph</td>
</tr>
<tr>
<td>inches</td>
<td>seconds</td>
<td>Inches per second</td>
<td>in/sec, ips</td>
</tr>
<tr>
<td>feet</td>
<td>minutes</td>
<td>Feet per minute</td>
<td>ft/min, fpm</td>
</tr>
</tbody>
</table>
Problems

When Evelyn Ashford was in the Olympics she broke the record for the 200 m run by completing it in 11s. What was her speed?

*Remember:* We have a specific 5-step method for solving problems...the GUESS method.
When Evelyn Ashford was in the Olympics she broke the record for the 200 m run by completing it in 11s. What was her speed?

G: write down the givens
you can do any necessary conversions at this point.

U: write down the unknowns

E: write down the equation(s)
you may want to re-arrange the equation at this point

S: write down the substitution

S: write down the solution
remember to include the units!

When Evelyn Ashford was in the Olympics she broke the record for the 200 m run by completing it in 11s. What was her speed?
The Pacific Plate moves at a pace of 8.1 cm/year. How far does the plate move in a century?

G: givens

$v = 8.1 \text{ cm/year}$

$t = 1 \text{ century} = 100 \text{ years}$

U: unknowns

$d = ?$

E: equation

$v = \frac{d}{t}$

Rearrange by multiplying sides by $t$

$vt = d$ or $d = vt$

S: substitution

$d = (8.1 \text{ cm})(100 \text{ yrs})$

S: solution

$v = 810 \text{ cm}, \text{ or } 8.1 \text{ m}$
In 1931, "'Big Bill' Tilden delivered the fastest serve ever officially measured. The speed was 73.14 m/s. If the serve covered 30.5 m, how much time did Bill’s opponent have to react before the ball reached him?

G: givens

U: unknowns

E: equation

S: substitution

S: solution
What is acceleration?

The rate at which velocity changes compared to the time it takes to change.

In other words:  \[
\text{Final Velocity} - \text{Initial Velocity} \quad \frac{\text{Change in speed}}{\text{Change in time}}
\]
What units do I use?

Velocity \( (\text{m/s}) = \) Change in distance \( (\text{m}) \)
Change in time \( (\text{s}) \)

And acceleration =

Change in Velocity
Change in time

Acceleration is a: \textit{speed unit divided by a time unit.}
Ex. velocity = m/s
time = s

acceleration = m/s/s or m/s^2
1. **Given:**
   - Initial Speed = 20 m/s
   - Final Speed = 60 m/s
   - Time = 4 seconds

2. **Unknown**
   - Acceleration = ?

3. **Equation**
   
   
   \[ a = \frac{v_2 - v_1}{t} \]

4. **Substitute**
   
   \[
   \text{acceleration} = \frac{60 \text{ m/s} - 20 \text{ m/s}}{4 \text{ sec}} = \frac{40 \text{ m/s}}{4 \text{ sec}}
   \]

5. **Solve**
   - Don’t forget units!
   
   Acceleration = 10 meters per second per second
More about acceleration....

*Any change in speed*, is acceleration.

*Any change in direction* is acceleration.

Let's say the stop light turns red and you put the brakes on. Are you accelerating?

**YES** - it is changing speeds!

The acceleration is in the *negative (opposite) direction*. This is also known as **deceleration**.
When is there zero acceleration?

If you are traveling at a **constant** speed of 50 mph for 1 hour, are you accelerating?

Remember –

Is your speed changing?

No? Then acceleration = \( \frac{50 \text{ mph} - 50 \text{ mph}}{1 \text{ hr}} = \frac{0 \text{ mph}}{1 \text{ hr}} = 0 \text{ mph} = \text{ZERO!} \)

*Acceleration is ZERO if you travel at a constant speed!*  
Zero acceleration = cruise control
All of the Equations

Based on what information you have, pick the correct equation!

The Kinematic Equations

\[ d = v_i t + \frac{1}{2} a t^2 \]
\[ v_f^2 = v_i^2 + 2a d \]
\[ v_f = v_i + a t \]
\[ d = \frac{v_i + v_f}{2} t \]
If a car can go from 0 mi/hr to 60 mi/hr in 8 seconds, what is its acceleration?
A car must come to an emergency stop. What is its acceleration if it took 8 seconds for it to stop when it was traveling at 30 m/s?
A cart rolling down an incline for 5.0 seconds has an acceleration of 4.0 m/s^2. If the cart has a beginning speed of 2.0 m/s, what is its final speed?
A car is accelerated at a rate of 3.0 m/s$^2$. If its original speed is 8.0 m/s, how many seconds will it take the car to reach a final speed of 25.0 m/s?
GRAVITY

- Pulls on ALL objects the same
- Without air resistance all objects will accelerate at exactly the same rate.
Gravity pulls all things down toward the center of Earth.

If you drop an object straight down and no other forces are acting on it, it accelerates in free fall.

Free Fall = 9.8 m/s² (also known as the acceleration of gravity)

In free fall, all objects accelerate at 9.8 m/s²
Gravity Problems

At what speed would a penny hit the water in a wishing well if it falls for 3.2 seconds?

G:
(For $v_1$: If I drop something what would its initial velocity be, when it is still in my hands?)

U:

E:

S:
Gravity Problems

If a water balloon is dropped out of a 2 story window and hits the person below at 14 m/s, how long was it falling?

G:

U:

E:

S:
Graphing Motion: Position and Time Graphs
P-T Graphs

- Distance runs vertically (the y-axis).
- The higher up the graph we go the further we are from the start.

- Time always runs horizontally (the x-axis).
- The arrow shows the direction of time.
- The further to the right, the longer time from the start.
If something is not moving, a horizontal line is drawn on a distance-time graph.

Time is increasing to the right, but its distance does not change.

This graph shows an object that is stationary.
If something is moving at a steady speed, it means we expect the same increase in distance in a given time.

Time is increasing to the right, and distance is increasing steadily with time.

This graph shows an object that moves at a steady, constant speed.
P-T Graphs

• Both the lines below show that each object moved the same distance, but the steeper yellow line got there before the other one.

• What does this indicate?

- A steeper slope indicates a larger distance moved in a given time. In other words, higher speed.
- This is shown in yellow.
P-T Graphs

- **Yellow**: speed = distance / time = 30 m / 10 s = 3 m/s
- **Blue**: speed = distance / time = 20 m / 20 s = 1 m/s
For the first part of the journey shown by the graph below, the object moved at a steady (slow) speed.

Then the object suddenly increased its speed, covering a much larger distance in the same time.

The speed increased in the second part of the journey.
There are three parts to the journey shown here... Where is the graph showing motion that is:

**Stopped?**

**Moving at a quick constant speed?**

**Traveling at a slow constant speed?**
What do these graphs, with a NEGATIVE SLOPE mean?

They show an object that is slowing down - or decelerating.

The first graph is slowly decelerating, while the second graph is quickly decelerating.
The graph shows where things are at different times.

When the slope is zero, the object is stopped.

When the slope is positive, the object is moving away from the starting point.
Position-Time Graph

Slope = \[ \text{change in rise} = \frac{\text{change in position}}{\text{change in run}} \]

***Velocity is the slope of a position-time graph
- Positive: Forward
- Negative: Backward
Instantaneous and Average Speed

- Average speed: the total distance of a trip divided by the total time
- Instantaneous speed: a very short distance divided by a very short time.

**Average Speed:**
For the entire trip, the average speed is $50 \text{ km} / 2 \text{ hr} = 25 \text{ km/h}$
Instantaneous and Average Speed

**Instantaneous speed:**

- In part A: \(10 \text{ km/0.5 hours} = 20 \text{ km/h}\)
- In part B: \(5 \text{ km/0.5 hours} = 10 \text{ km/h}\)
- In part C: \(15 \text{ km/0.25 hours} = 60 \text{ km/h}\)
- In part D: \(20 \text{ km/0.75 hours} = 27 \text{ km/h}\)
YOU TRY IT: GRAPHING POSITION VS. TIME

• Suppose you are helping a friend who is training for a track meet.
• She wants to know if she is running at constant speed.
• You mark the track in 50-meter increments and measure her time at each position during a practice run.
• Create a position-time graph using her data.
• Calculate her average speed.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Position (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>150</td>
</tr>
</tbody>
</table>
COME ON UP!!!

Calculate Speed:
Graph the motion of this car.
COME ON UP!!!

Calculate Speed:
Now consider a car that has a changing velocity.
It is not moving at a constant rate, but getting faster by the second.

What would this graph look like?
You try it in your notes first…
Does your graph look like this? Be sure you have this one drawn.
P-T Graphs: Acceleration

• The line below is curving upwards. This shows an increase in speed, since the slope is getting steeper over time.

• It is accelerating
Acceleration in a P-T Graph

- **Increasing Speed (acceleration)**
  
  ![Graph showing increasing speed](image1)

- **Decreasing Speed (deceleration)**
  
  ![Graph showing decreasing speed](image2)
How Can You Create the Following Position Graphs?

Graph 1.

```
X (m)  
10 10  
```

Graph 2.

```
X (m)  
0 0  
```

Graph 3.

```
X (m)  
0 0  
```

Graph 4.

```
X (m)  
0 0  
```

A. Speed Up  
B. Turn Around  
C. Slow Down  
D. Stand Still
Speeding Up While Falling

- What could cause this?

Object being dropped!
Free Fall/Gravity on a P-T Graph

• Trajectory of a ball being thrown upward
Free Fall/Gravity on a P-T Graph

Figure 2: Position vs. Time

What is happening at each point?
Free Fall/Gravity on a P-T Graph

What is happening at:
J: Decelerating  K: Decelerating  L: Decelerating
M: Stopped  N: Accelerating  O: Accelerating
P: Accelerating

- Gravity is fighting the upward motion of the object on the way up, so the acceleration is -9.8 m/s/s (negative)

- Gravity is making the object move faster on the way down so the acceleration is 9.8 m/s/s
You just finished designing your own *Hot Wheels* car and you are ready to race it down the driveway. You take out your stopwatch and record the time from start (zero) to the end of the driveway. You then calculated the speed and created a chart. Let’s take a look at how your car did.

What would a velocity vs. time graph look like with this data?

*Do it in your notes!*
What does the slope of a velocity vs. time graph tell you?

Remember:

Slope = rise/run = 

(change in speed)/(time)

What else have we talked about that’s formula is (change in speed)/(time)?

Acceleration = Change in Speed/Time

So...the slope of a speed vs time graph gives us acceleration!
The graph shows a slope with a straight line.

According to the graph, what does this tell you about the acceleration?

→ Straight line, so same slope
→ Your car accelerates the same amount every second (constant acceleration)

How much is your car accelerating every second?
What to know about the speed vs. time graph....

*If you see a slope, you are seeing acceleration*

A = **upward slope** = positive acceleration, speeding up

B = **downward slope** = negative acceleration, slowing down also known as **deceleration**,

C = **No slope** (completely horizontal) = zero acceleration, but constant speed, so object is still moving unless the line is at zero
Learning Check

1. What is occurring during A, B, C?

2. If a speed vs. time graph line has no slope, is the car moving?
   **Yes! It is still moving at a constant speed**

3. What is the formula for acceleration?
   \[ a = \frac{\text{change in speed}}{\text{change in time}} \]

4. Rearrange the formula to solve for:
   - Time
   - Final Speed
Comparisons

Distance – Time graph

Speed – Time graph

Distance (m) vs. Time (s)

Speed (m/s) vs. Time (s)